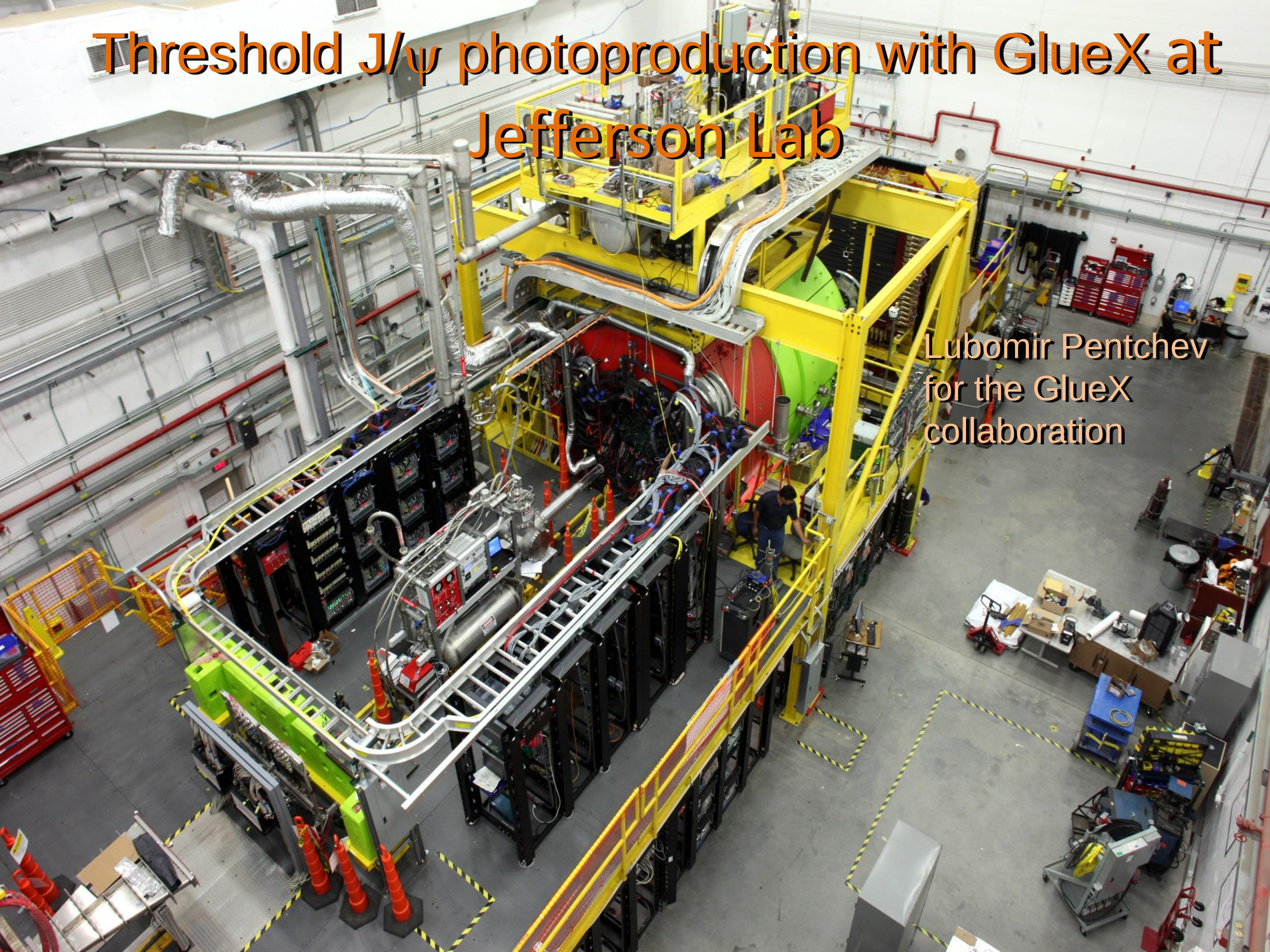
Threshold J/ψ photoproduction with GlueX at Jefferson Lab

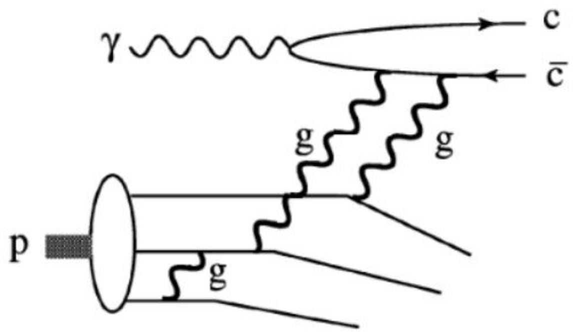


Lubomir Pentchev
for the GlueX
collaboration

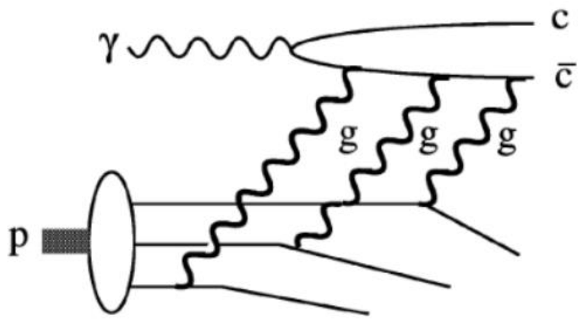
Why study J/ψ near threshold photoproduction

- Poorly covered by old measurements
- 12 GeV CEBAF at JLab – high intensity and right energy
- GlueX coherent Bremsstrahlung peak right above the threshold – improved statistics at the very important point
- Sensitive to proton gluonic content at high x:

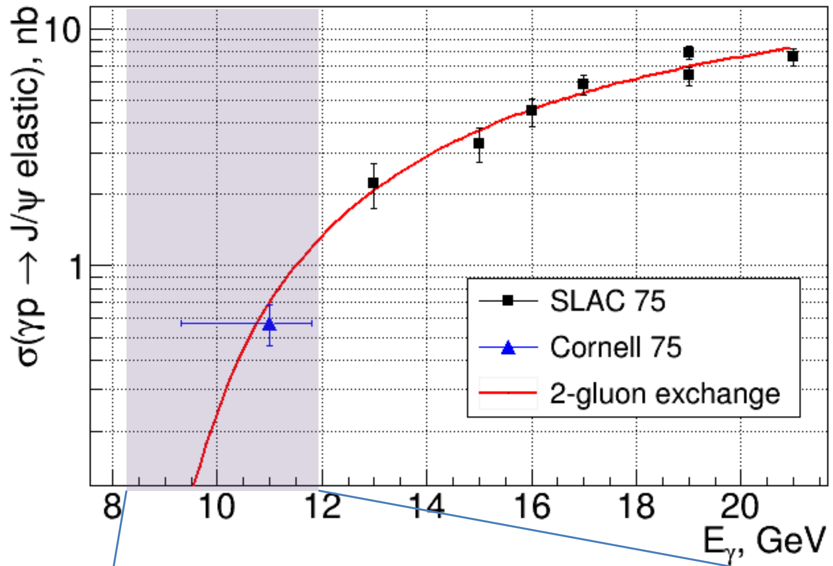
Brodsky et al. PLB 498, 23 (2001)

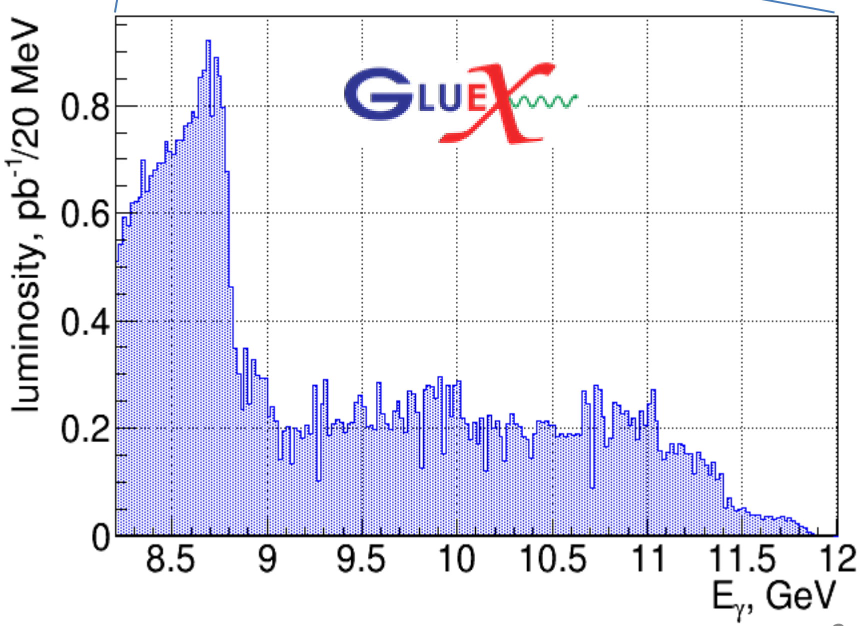


two-gluon exchange



three-gluon exchange





Why: J/ψ threshold photoproduction and the mass of the proton

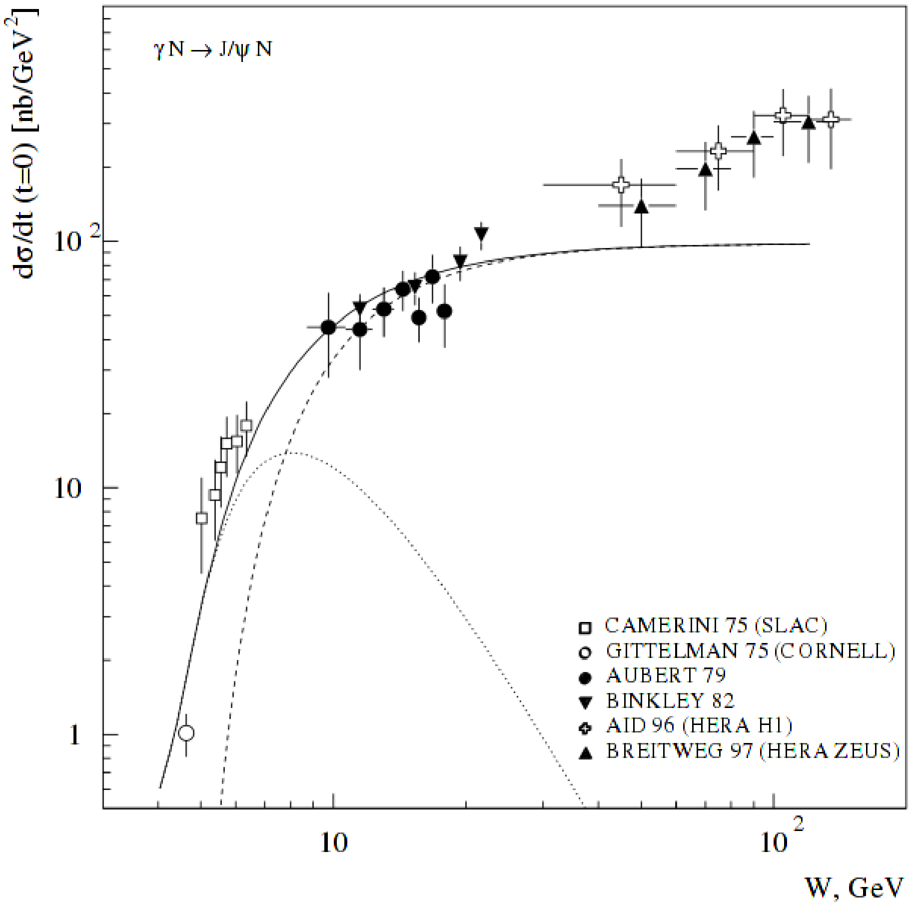


Fig. 1. Forward J/ψ photoproduction data compared to our results with (*solid line*) and without (*dashed line*) the real part of the amplitude; the dotted line shows the real part alone. The curves were obtained using a scaling PDF [4].

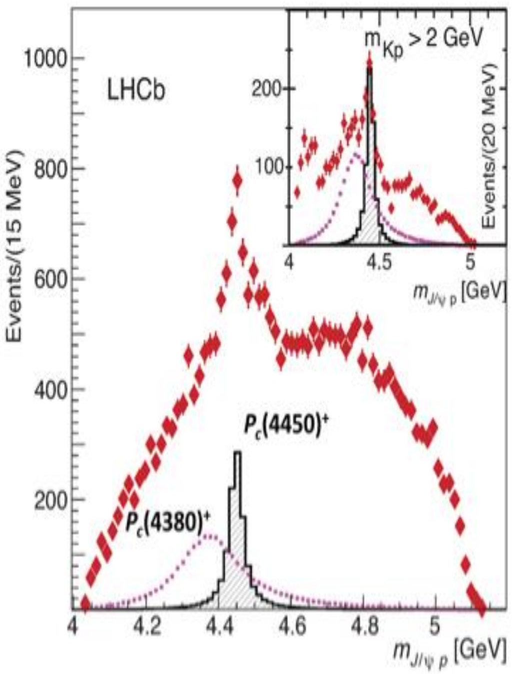
Reflects the gluon distribution in the nucleon:

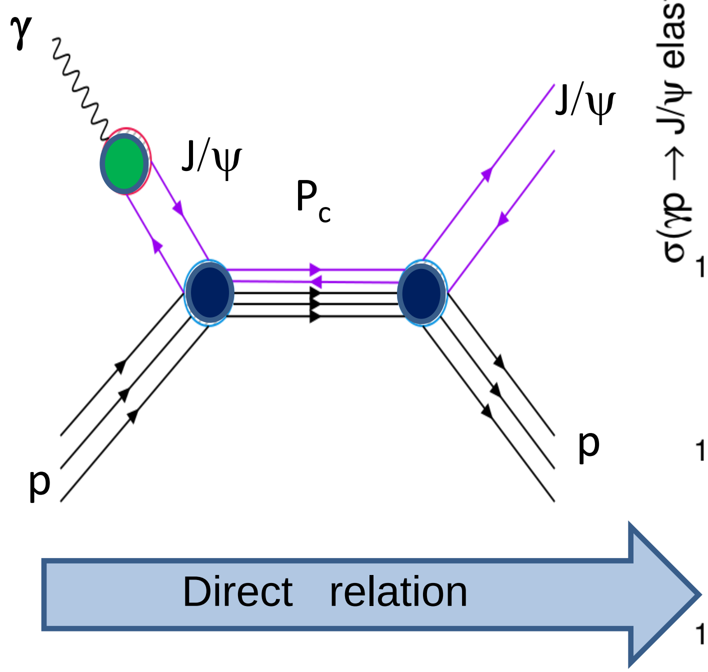
Kharzeev et al. Eur. Phys. C9 (1999) – perturbative calculations using gluon PDFs

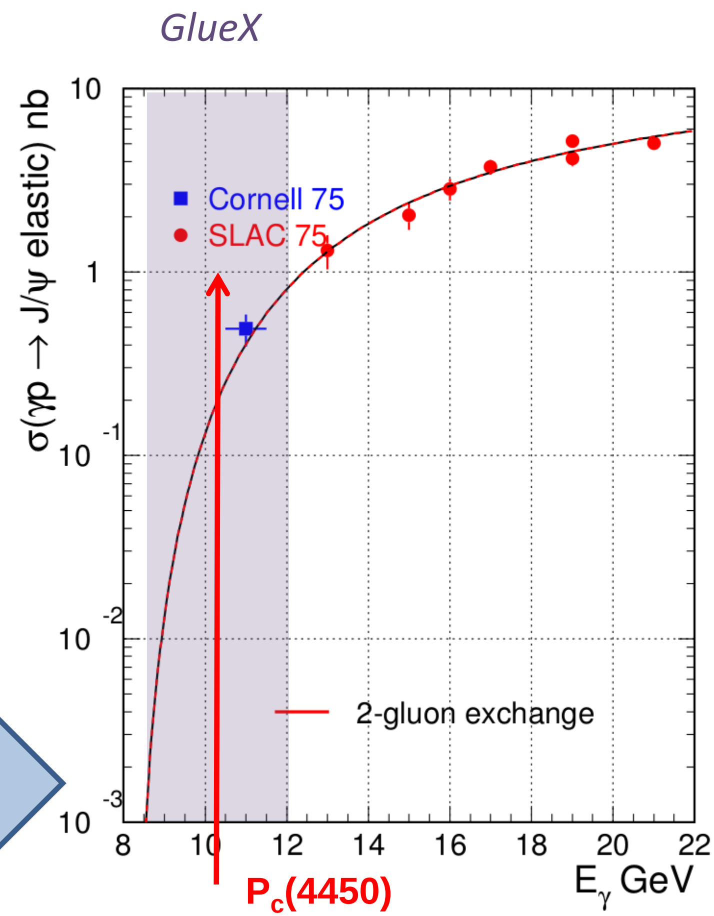
The real part of the amplitude (dominates at low energies) is critically important – contains the conformal (trace) anomaly, related to the fraction of the nucleon's mass arising from gluons.

Why: LHCb petaquarks in s-channel production

- Also because of the LHCb pentaquarks - DIRECT relation – if they exist they should be seen in s-channel photoproduction:

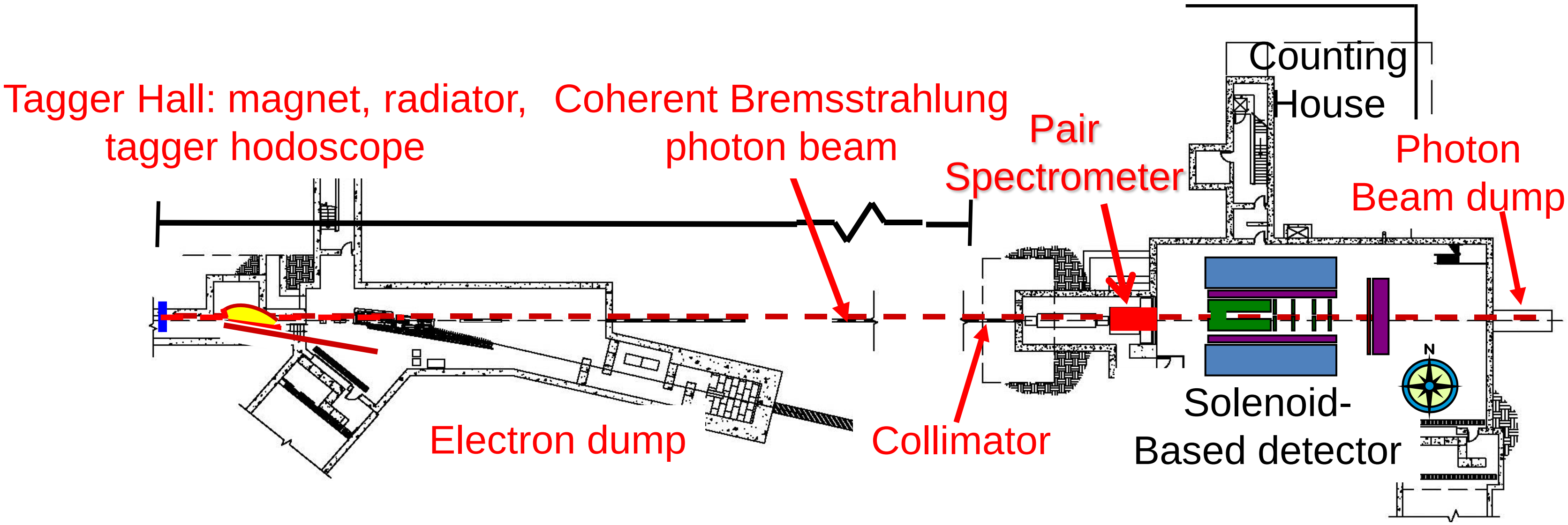






- V.Kubarovsky and M.B.Voloshin, PRD 92.031502 (2015).
- M.Karliner and J.Rosner, arXiv: PLB 752, 329 (2016).
- A.Blin, C.Fernandez-Ramirez, A.Jackura, V.Mathieu, V.Mokeev, A.Pilloni, and A.Szczepaniak, PRD 94,034002 (2016).

Hall D at 12GeV CEBAF (JLab, VA USA)

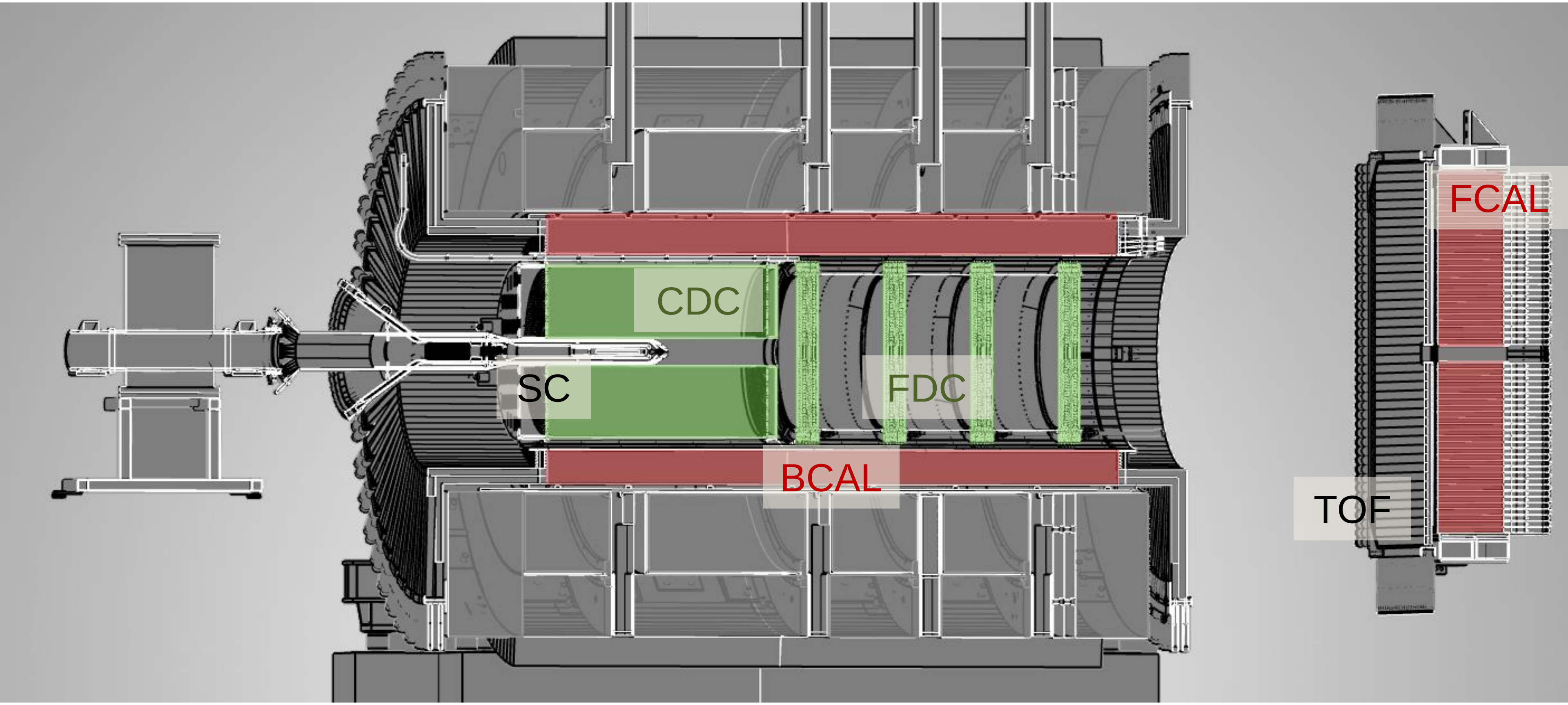


- Photon energy tagged by scattered electron ~ 0.1% resolution
- Photon beam collimated at 75m, <25 μrad
- Intensity: ~ 2 10^7 **-** 5 10^7 γ/sec above J/ψ threshold (8.2 GeV) – total ~68 pb^{-1} in 2016-2017 runs

GlueX detector

2T-solenoid, LH target

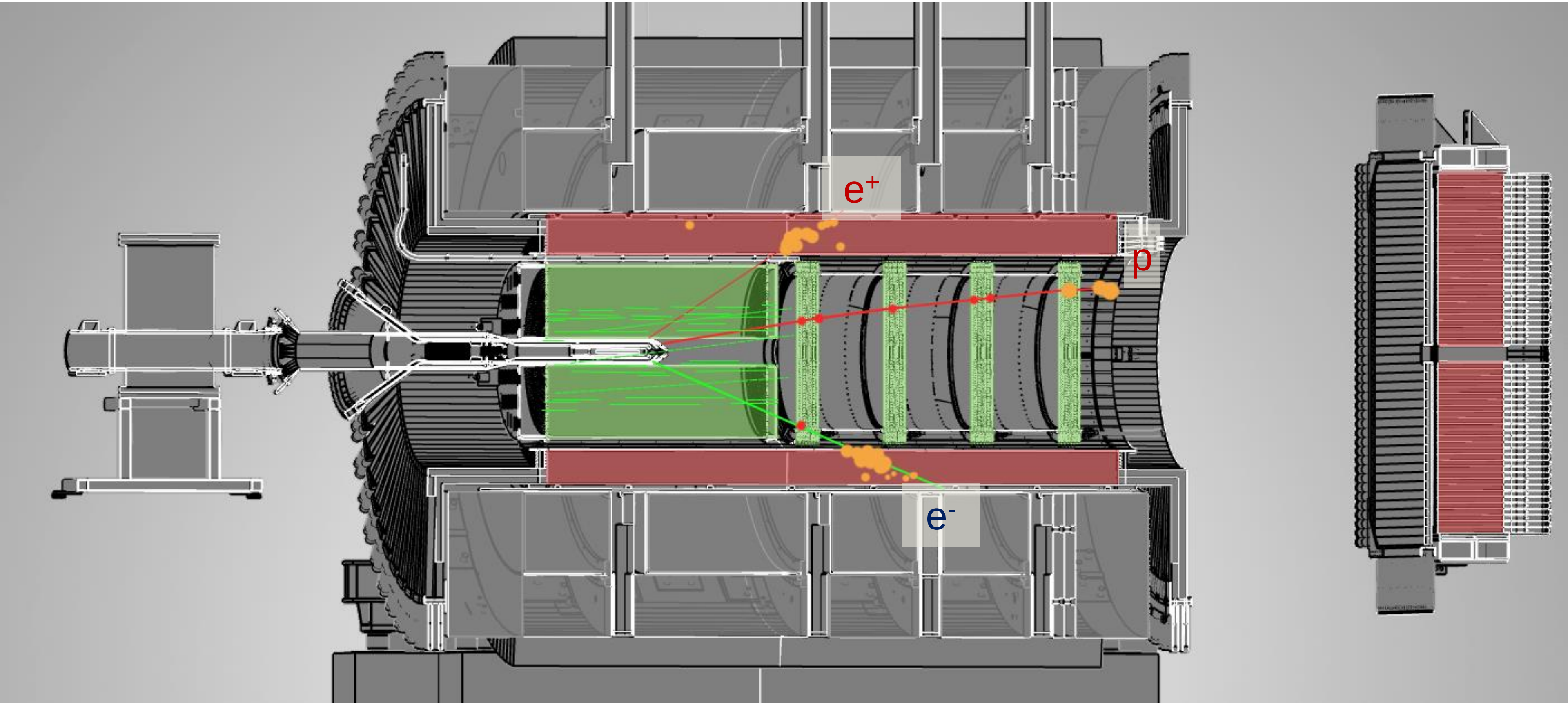
Tracking (FDC,CDC) , Calorimetry (BCAL,FCAL) , Timing (TOF,SC)



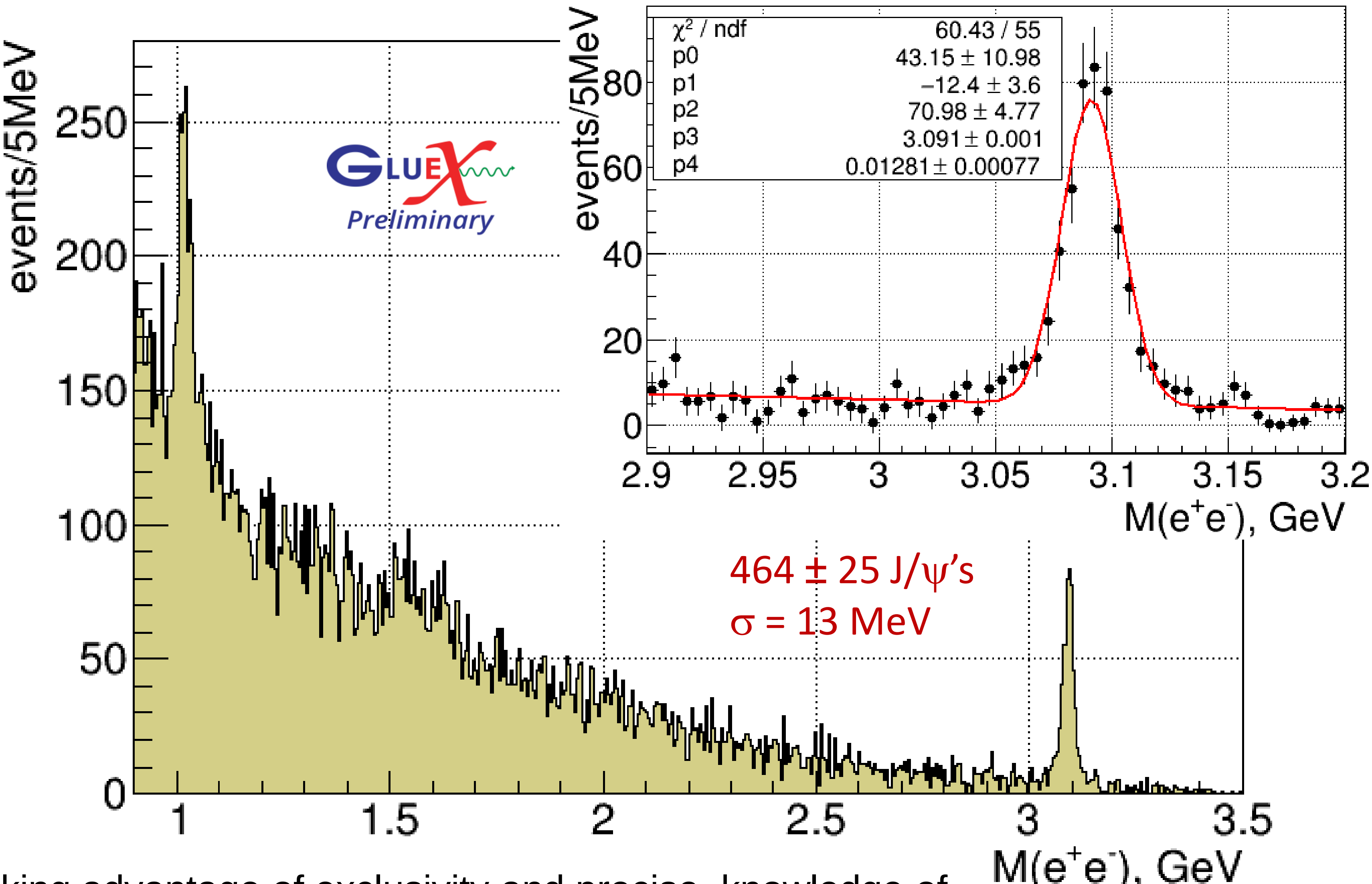
- Hermetic detector: 1 – 120° polar and full azimuthal acceptance
- Tracking: σ_p/p ~ 1 – 5%
- Calorimetry: $\sigma_E/E \sim 6\%/\sqrt{E} + 2\%$

J/ψ event

Exclusive reaction $\gamma p \rightarrow J/\psi p \rightarrow e^+e^-p$

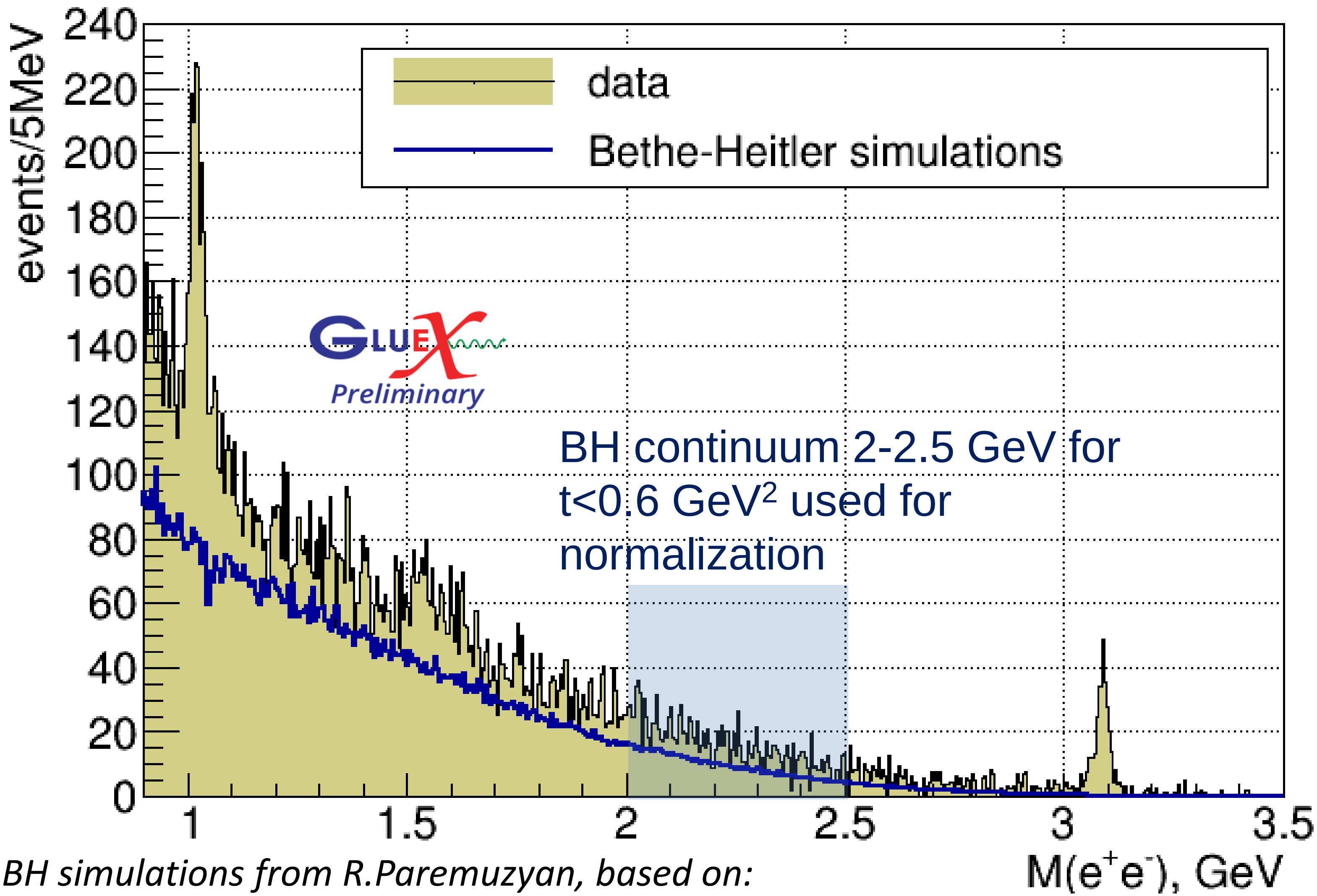


Di-electron mass spectrum



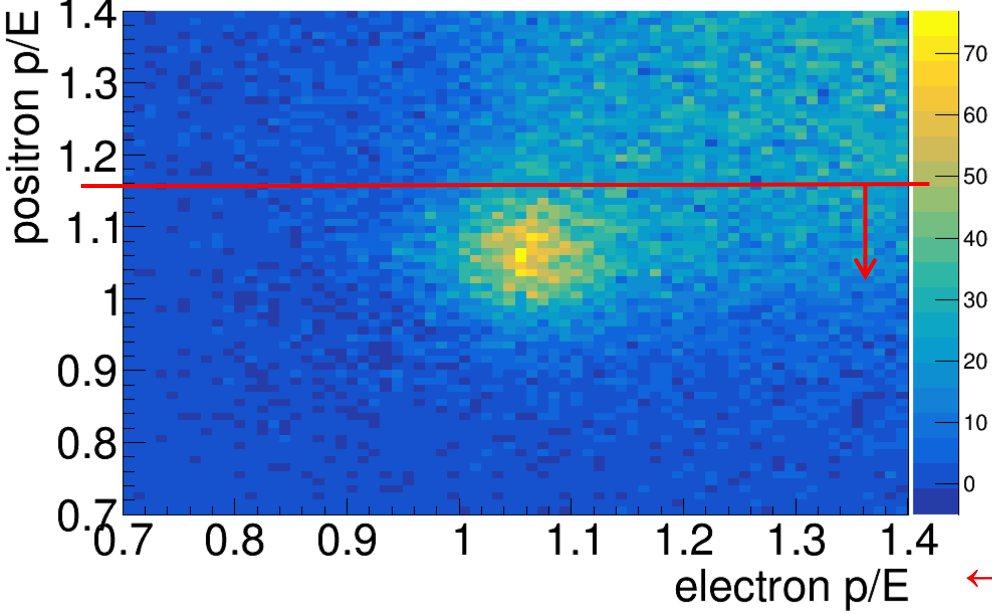
Taking advantage of exclusivity and precise knowledge of beam energy –> kinematic fit gives high resolution

Di-electron mass spectrum

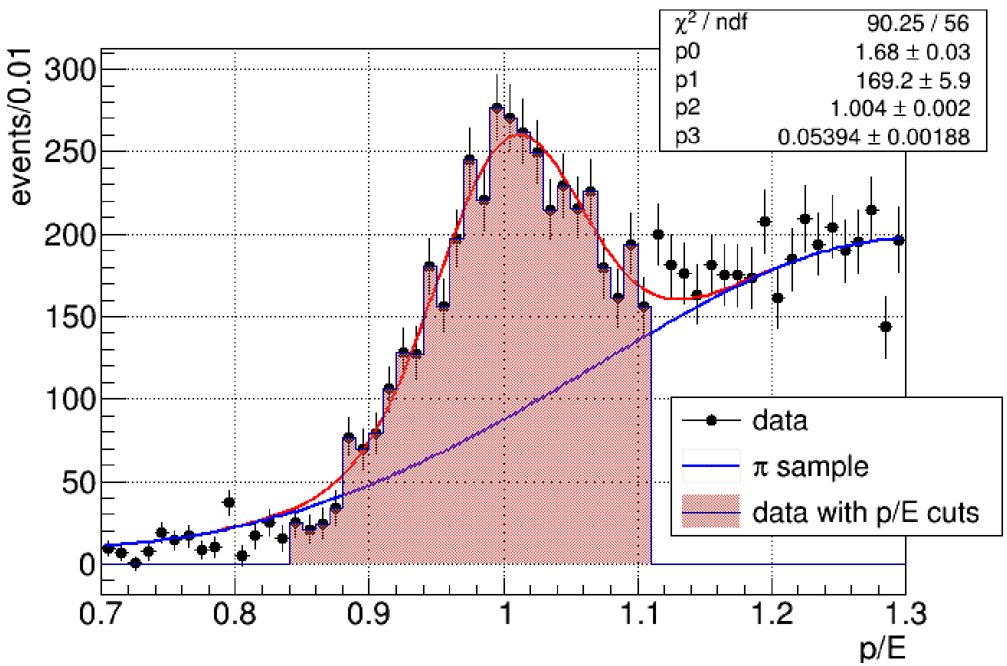


- *BH simulations from R.Paremuzyan, based on:*
- *Berger, E., Diehl, M. & Pire, B. Eur. Phys. J. C (2002) 23: 675.*

Electron/pion separation using E(calorimetry)/p(tracking)

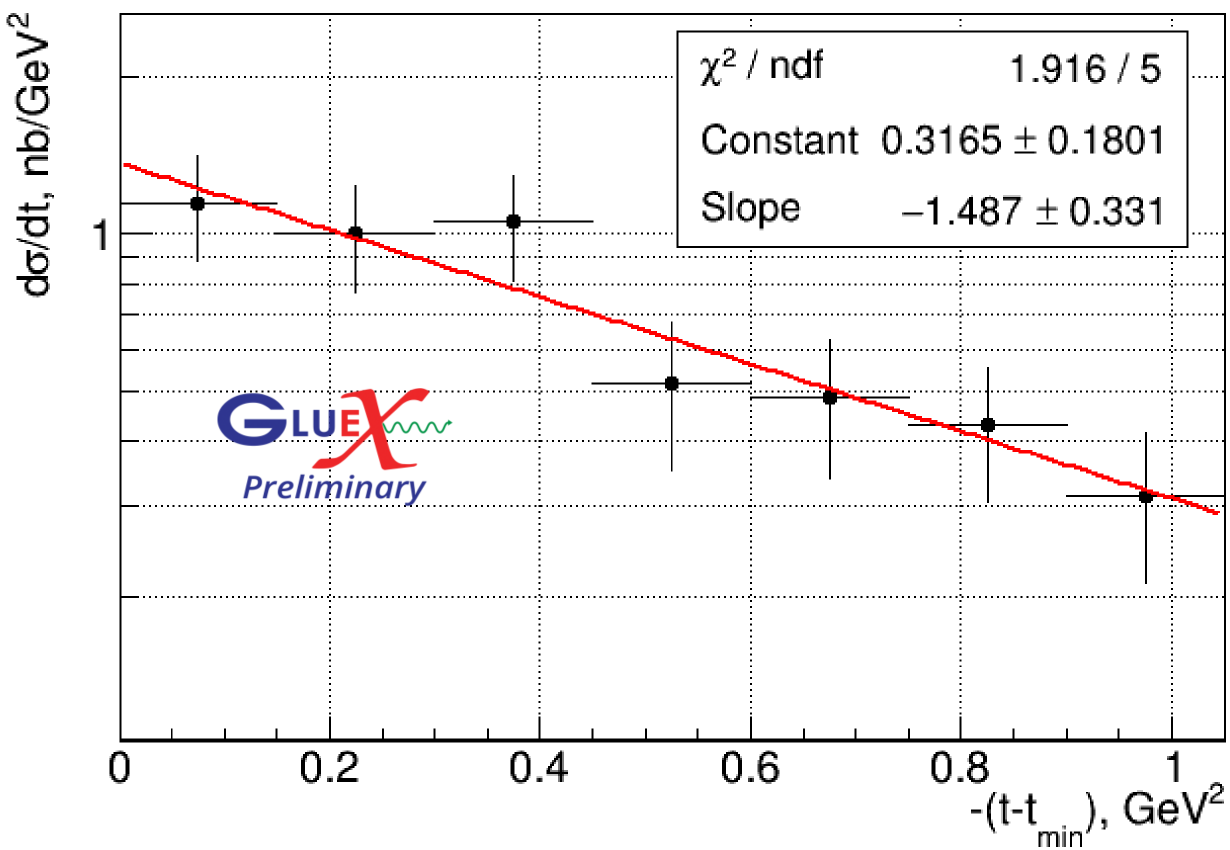


← Note p/E on plots!



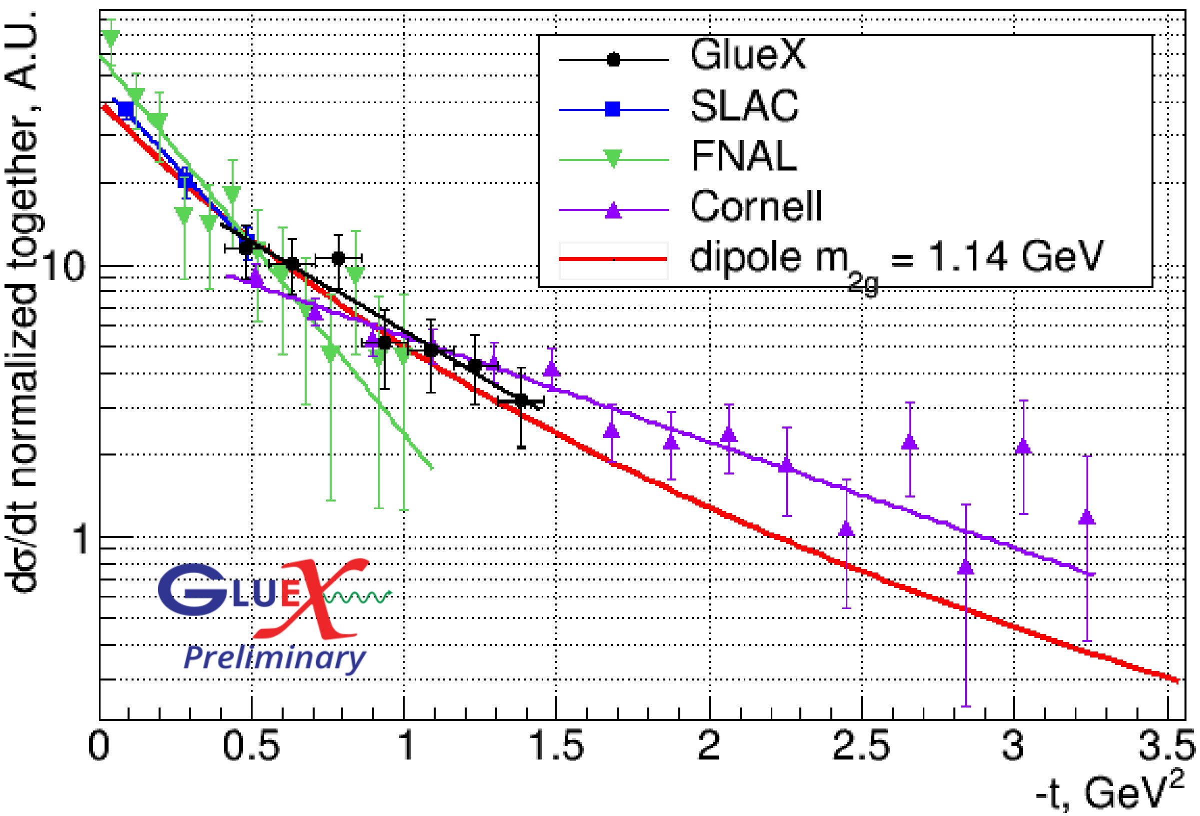
- 51±1.3% π contamination in 2-2.5 GeV M(e^+e^-) region with 2σ cut on electrons and t<0.6 GeV2
- BH yields corrected in bins of energy
- Background shape from pion sample (E /p anti-lepton cuts)

Preliminary results: t-dependence



- Cornell at 11 GeV
  1.25±0.20 GeV^{-2}
- Gluex at 10-11.8 GeV
  1.487±0.33 GeV^{-2}
- SLAC t-slope at 19 GeV
  2.9±0.3 GeV^{-2}

Proton Gluonic Form Factor

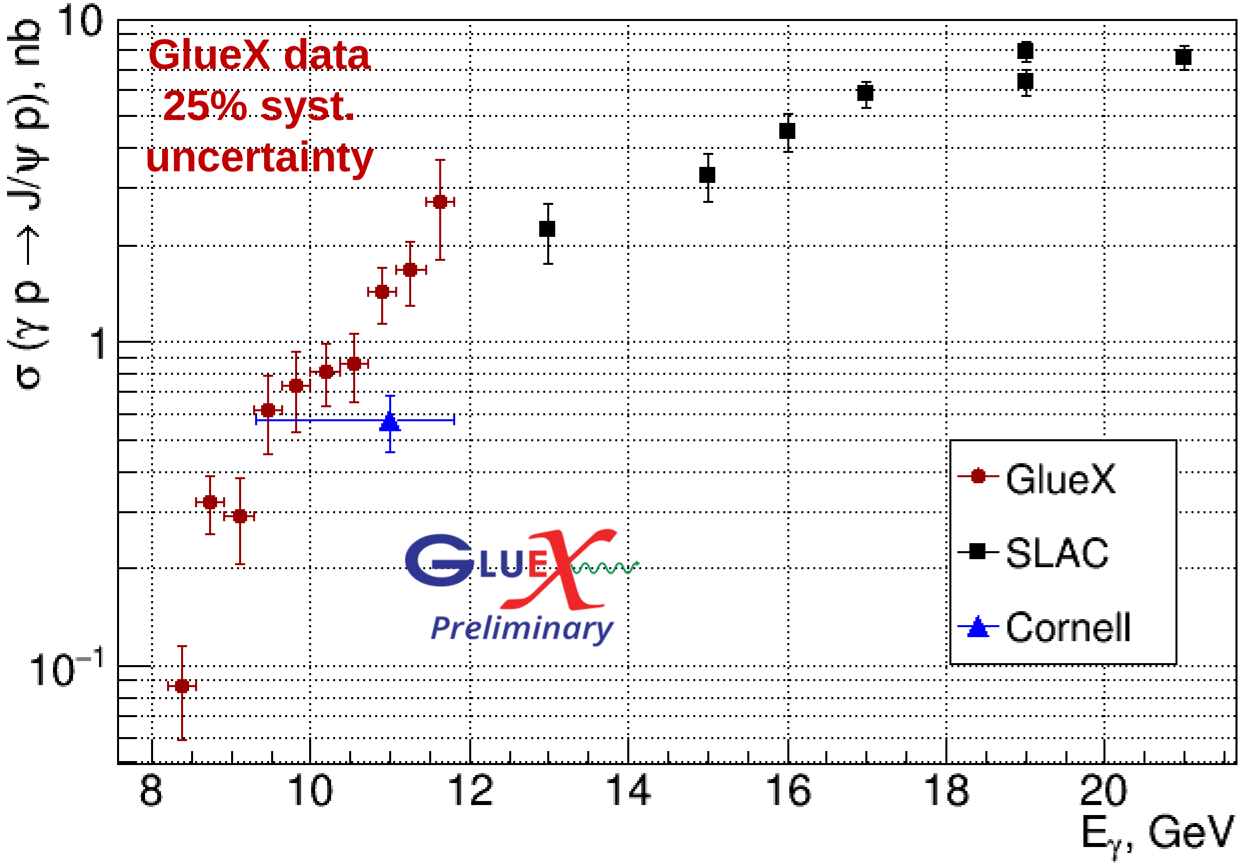


- *Frankfurt and Strikman PRD66 (2002)* suggested t-dependence defined by the proton gluonic FF
- Explains t-slope change with energy (due to t_{min} and t-range dependence) in wide energy range:
  - FNAL <E>=100 GeV
  - SLAC 13-21 GeV
  - Cornell 11 GeV
  - GlueX 10-11.8 GeV

Using VMD ($\gamma \to J/\psi$) one can study
$J/\psi\ p \to J/\psi\ p$

$$F(t) \sim \frac{1}{(1-t/m_{2g}^2)^4}$$

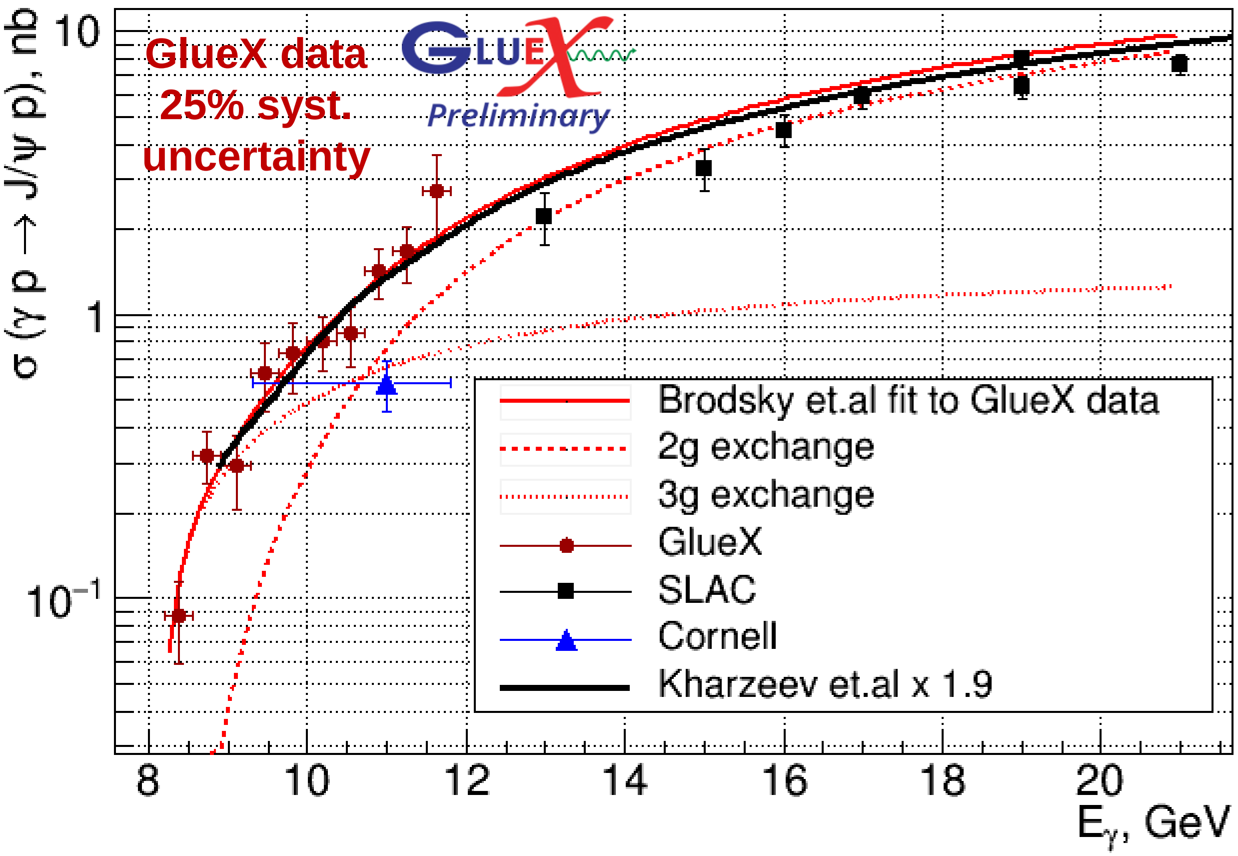
Preliminary results: beam energy dependence



Using F(t) to calculate total cross-section from the SLAC dσ/dt at t_{min}

Cornell data: horizontal errors represent acceptance

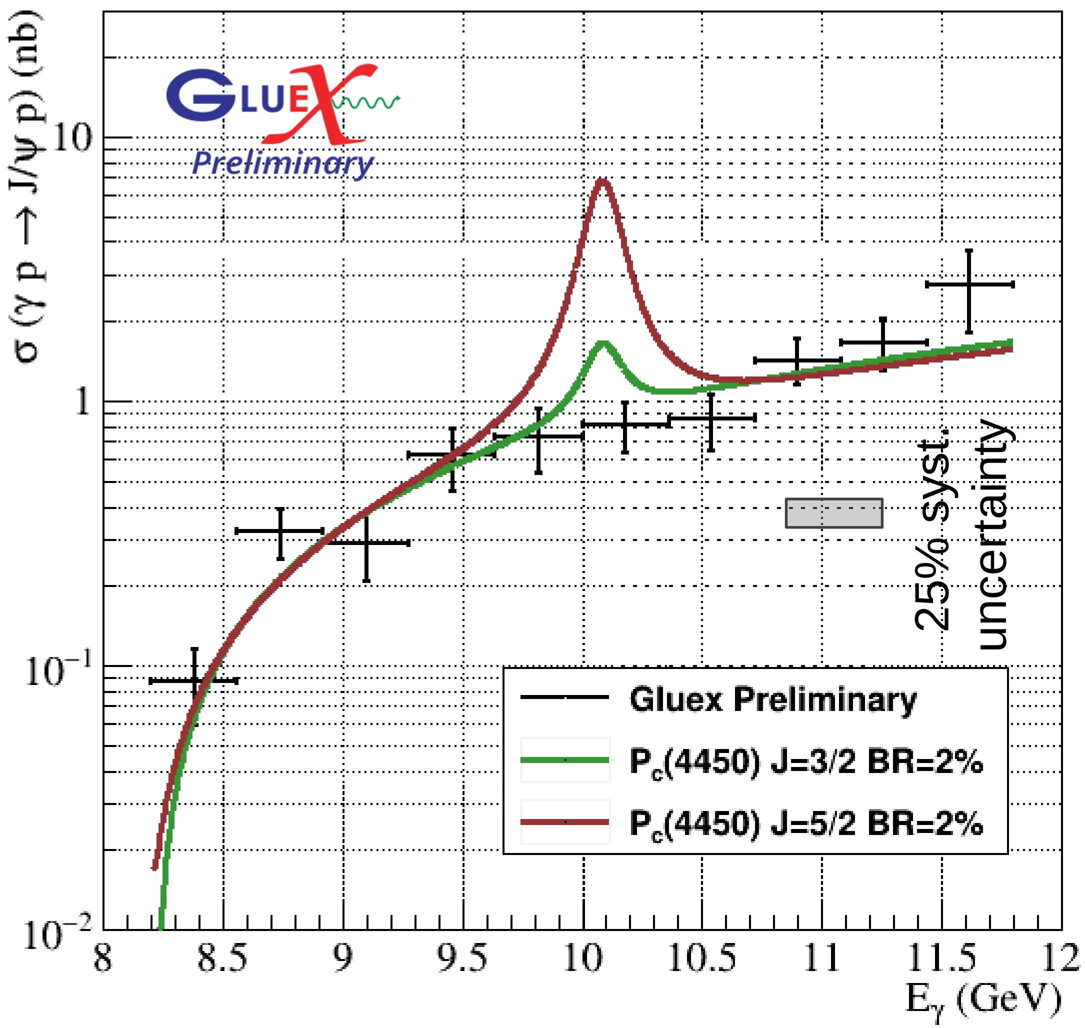
Preliminary results: comparison to theory



Brodsky at.al (2001)
fit of the GlueX data ONLY, using F(t) as t-dependence

Kharzeev et al (1999)
absolute (factor 2-3 uncertainty) perturbative calculations using gluon PDFs - related to the gluonic contribution to the mass of the proton

J/ψ cross-section and pentaquark predictions



2%BR P_c(4450) 5/2+

2%BR P_c(4450) 3/2-

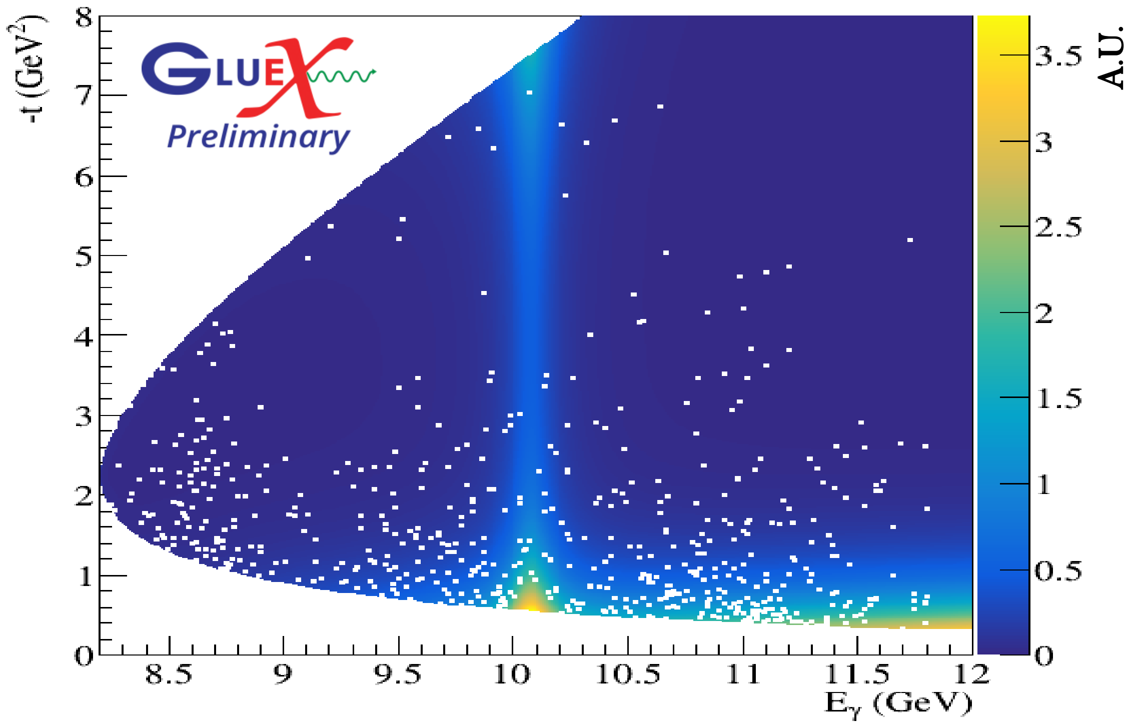
Based on simple analysis can set (3σ separation) limit on the BR Pc(4450)→J/ψp of ~2% for $3/2^-$ and even lower for $5/2^+$ hypothesis

Systematic:

- t-s channel interference: model used assumes Pomeron exchange - imaginary amplitude, while Kharzeev et.al predicts domination of real part
- Pc(4380) not included in the analysis

A.Blin, C.Fernandez-Ramirez, A.Jackura, V.Mathieu, V.Mokeev, A.Pilloni, and A.Szczepaniak, PRD 94,034002 (2016).

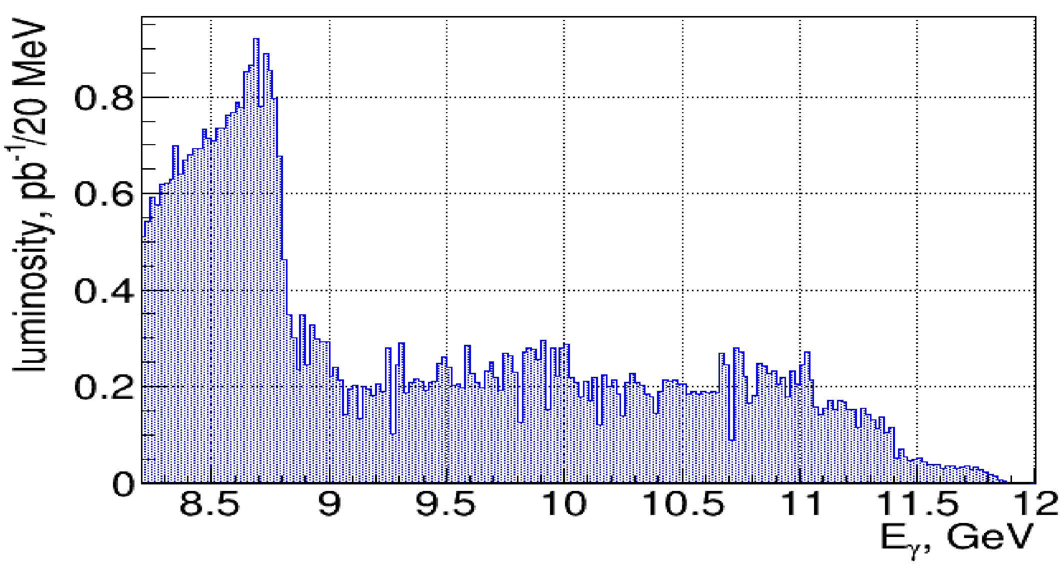
t vs Eγ unbinned distribution for J/ψ events



dots – GlueX data

color – model prediction from JPAC for 2%BR $P_c(4450)$ $5/2^+$

A.Blin, C.Fernandez-Ramirez, A.Jackura, V.Mathieu, V.Mokeev, A.Pilloni, and A.Szczepaniak, PRD 94,034002 (2016).

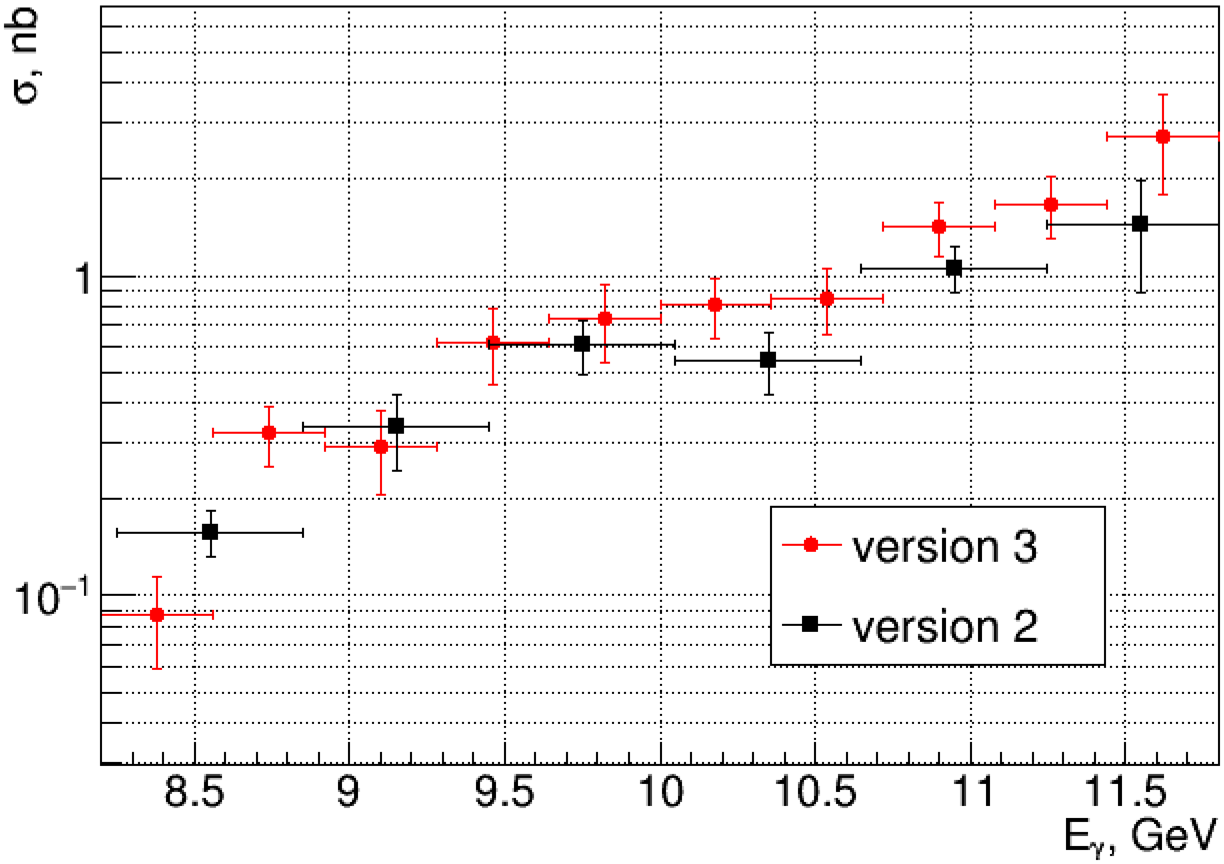


- Density of data points proportional to flux and efficiency
- No significant variations of flux (E_γ>9 GeV) and efficiency
- ~20% of dots background and accidentals

Summary

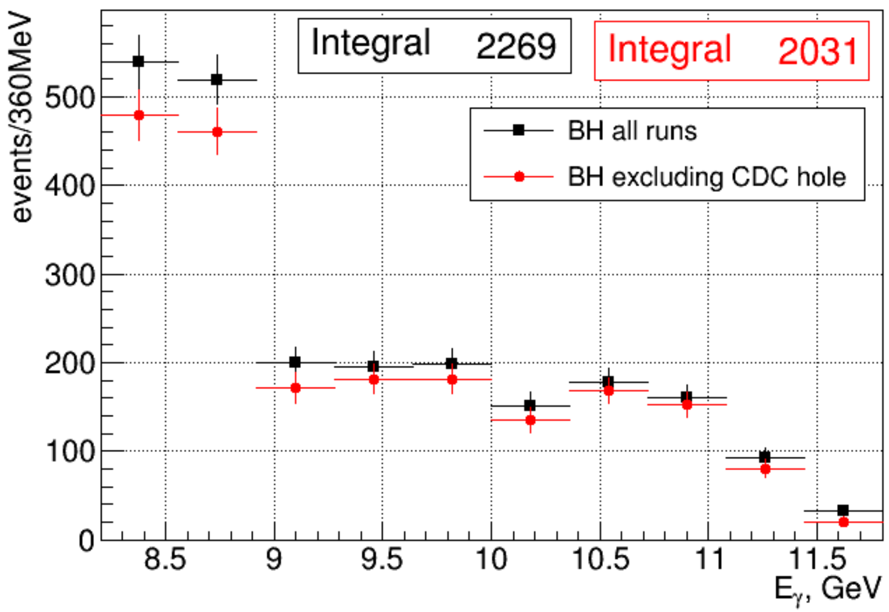
- JLab 12GeV accelerator has UNIQUE opportunity (high intensity, correct energy, polarized beam) to study J/ψ photo-production right above the threshold (E_γ=8.2 GeV) up to 12 GeV
- First measurements that extend down to the threshold – can be used to study the production mechanism; related to the fraction of the nucleon's mass arising from gluons
- Preliminary cross-section results suggest domination of 3-gluon exchange at the threshold
- Preliminary t-differential cross-section (together with world data) supports the dipole form of the t-dependence allowing to study the Proton Gluonic Form Factor
- The results show domination of the t-channel and no evidence for the LHCb pentaquark. Can set a limit for Pc(4450)→J/ψp BR at a few percent level

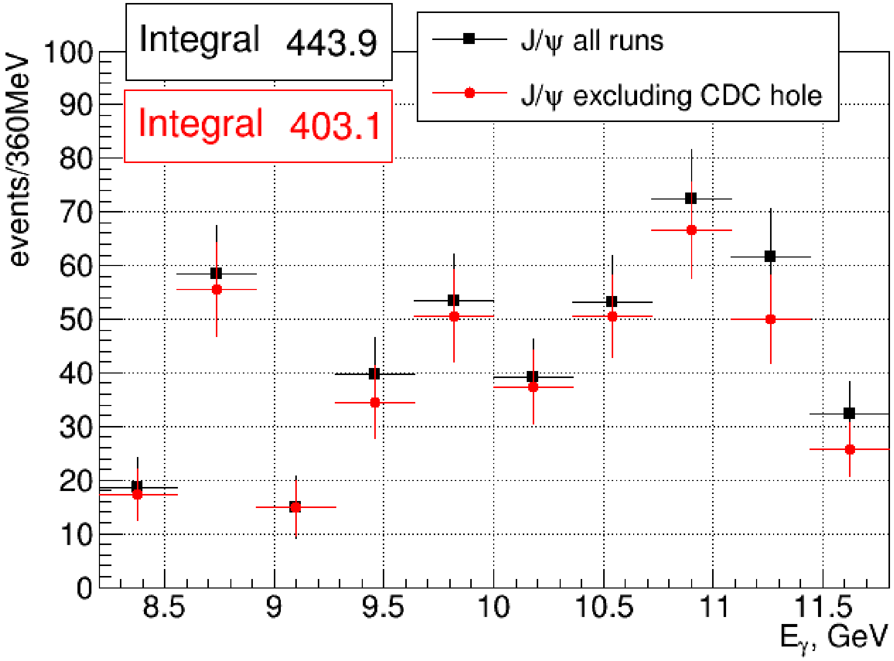
Addressing several issues/questions
Matt: old preliminary vs new results

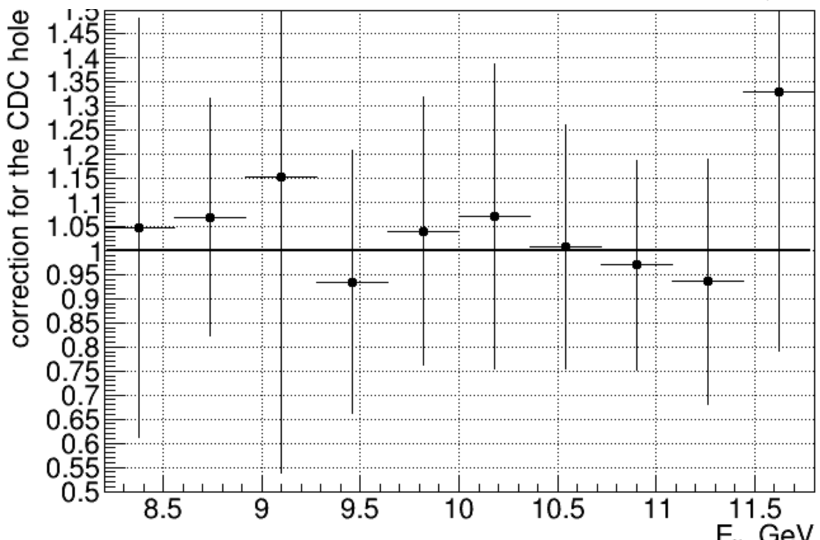


- Up to 10GeV similar
- >10GeV ~20% higher – within claimed systematics 30% (19% J/psi to BH efficiency)
- Ver.3 factor of 2.2 more statistics and only ~60% of ver.2 appears in ver.3
- BH range change 1.5-2.5 (ver2) 2-2.5 (ver3)

Addressing several issues/questions:
Elton: CDC "hole" runs



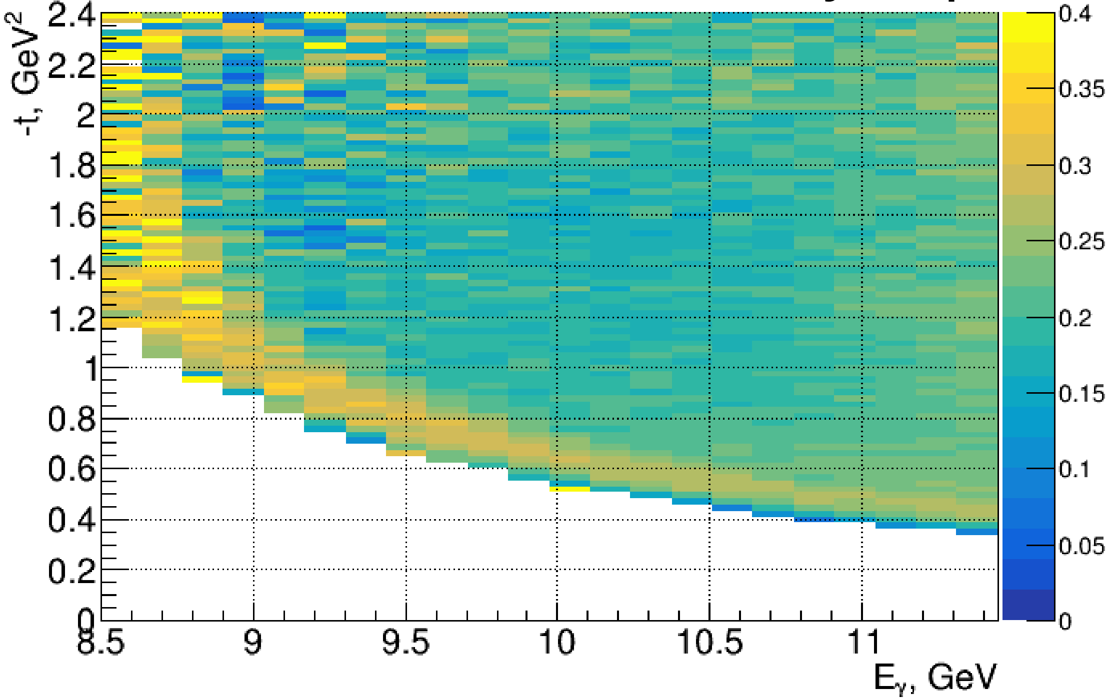




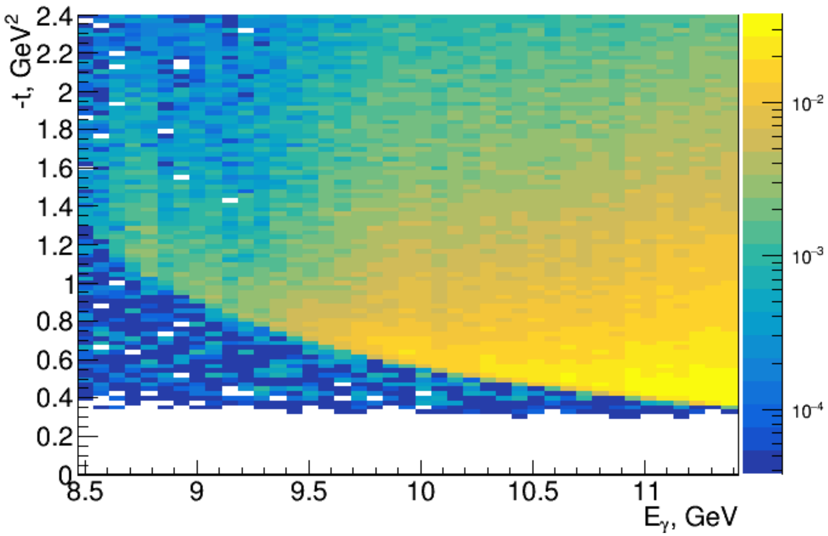
Correction small except last point:

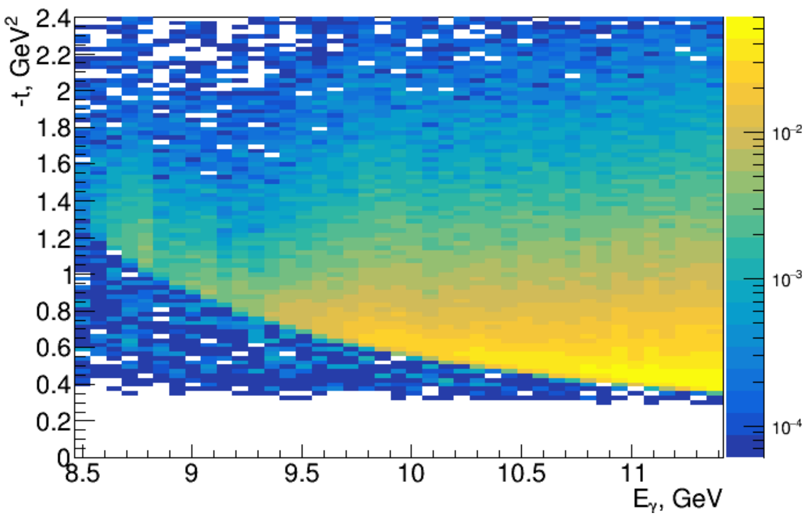
- Only 2016
- BH 32 -> 19 events
- J/psi 32 -> 25 events
- Statistically similar changes
- 3% of CDC channels affected

Addressing several issues/questions
Mark D.: efficiency dependence on t-slope



Due to strong E-t correlation (t_min changes with energy) t-slope affects the efficiency as function of t.





Addressing several issues/questions
Ryan: method, quality of the fits, width fluctuations

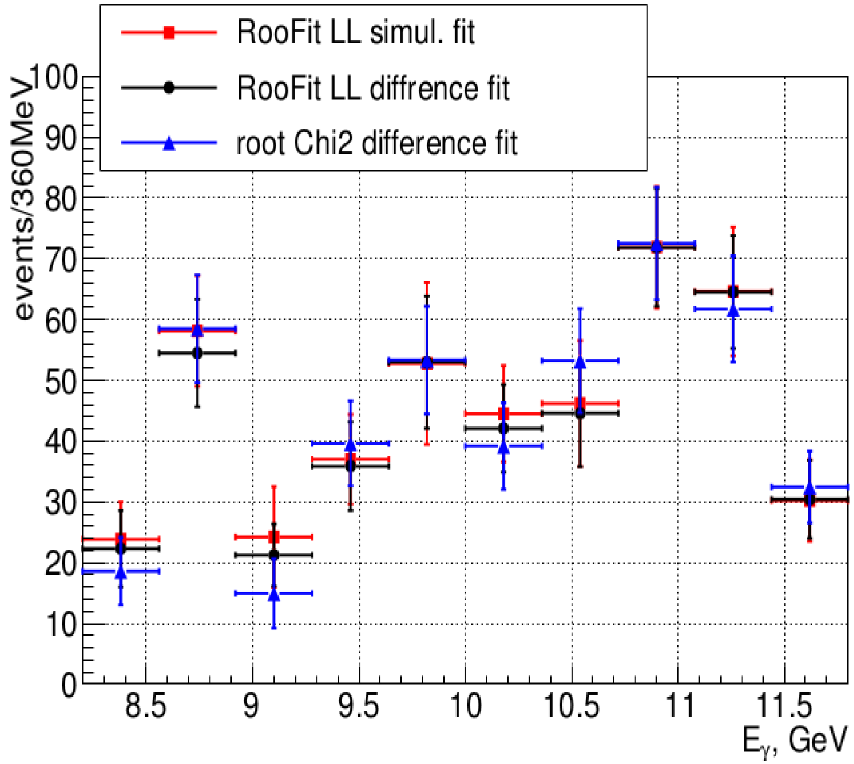
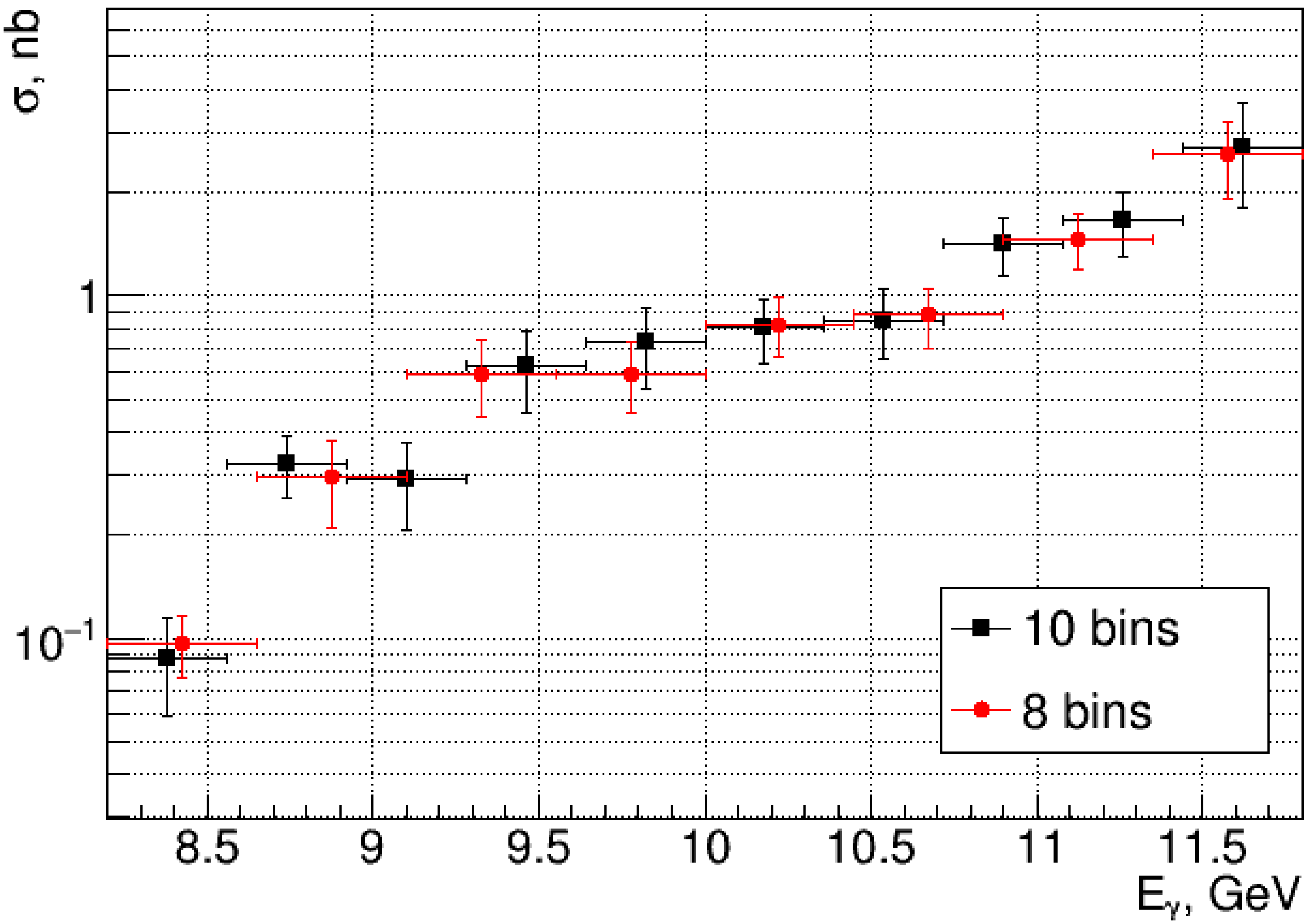


FIG. 28: Yields from Figs.25,26,27 estimated with different methods: simultaneous fit of signal and accidental distributions using extended binned weighted likelihood with *RooFit* (red), same as before but fit the difference (black), fit of the difference using χ^2 fit with *root* (blue).

Addressing several issues/questions
Ryan: method, quality of the fits, width fluctuations



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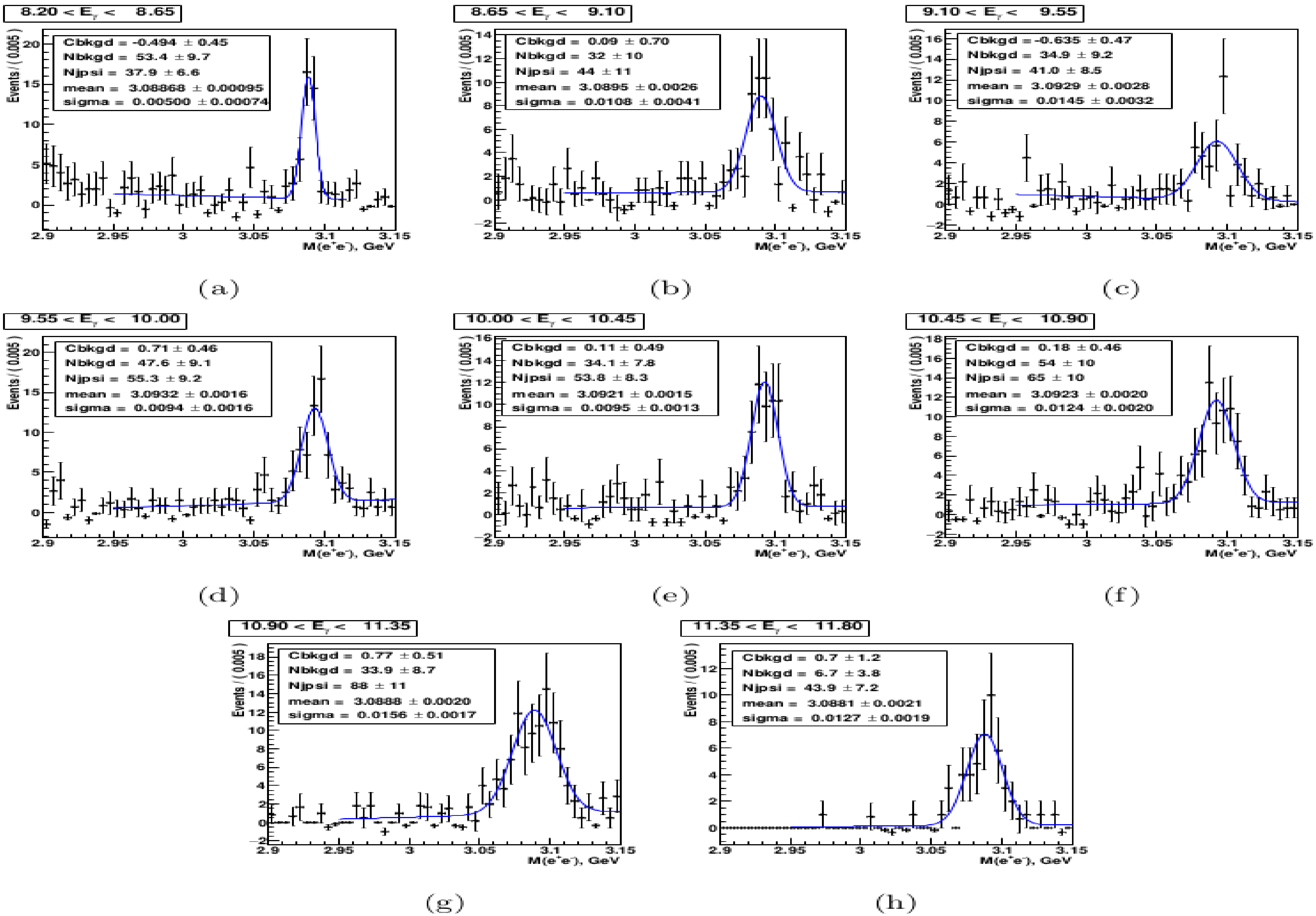

FIG. 43: Fits in 8 bins of beam energy using Method (II)

Back-ups